Extending the scope and improving the accuracy of migratory bird monitoring with automated acoustic techniques

Kurt M. Fristrup, Thomas A. Calupca

Bioacoustics Research Program
Cornell Laboratory of Ornithology

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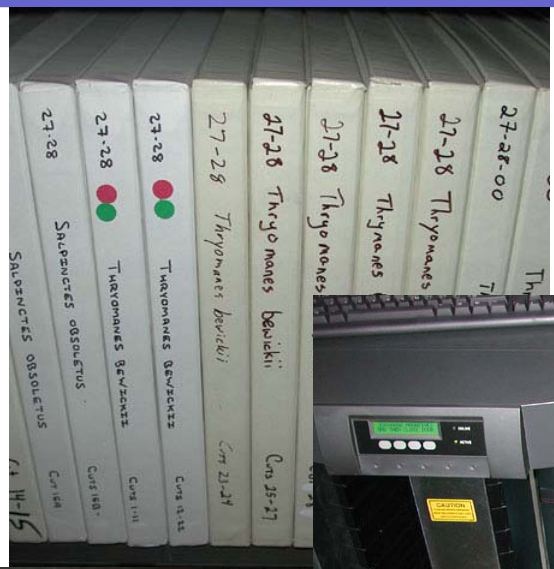
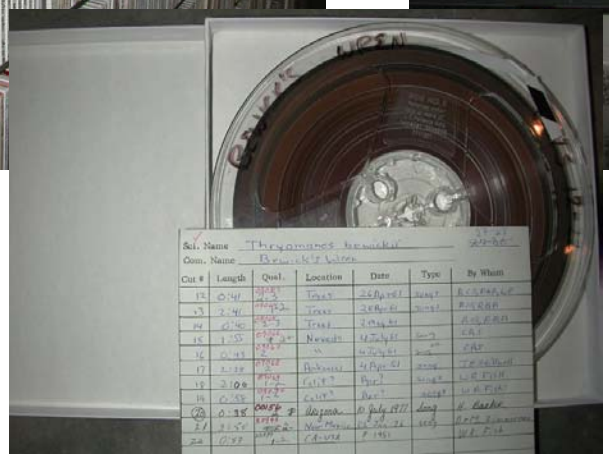
A Long-Standing Tradition of Innovation

Imogene Powers Johnson Center for Birds and Biodiversity

Macaulay Library





150,000 recordings, >8000 species, 70% of the world's birds

World's largest natural sound library

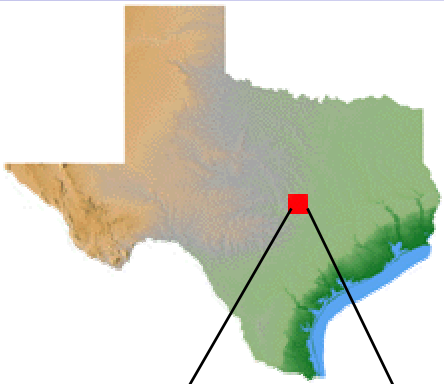
Why Sound?

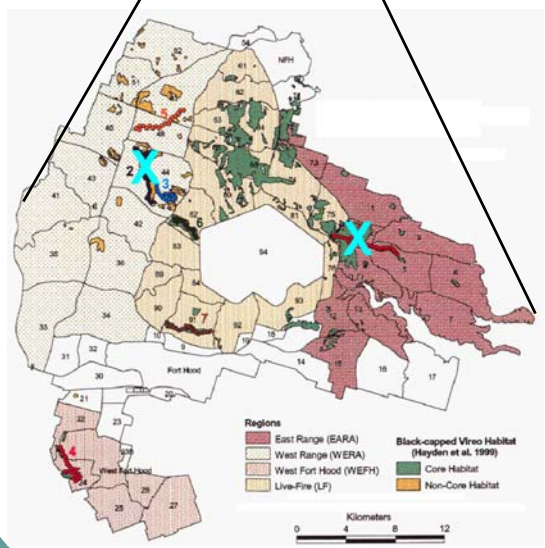
- ALL verterbrate and most invertebrate species can hear sounds; many species produce sounds
- Most bird survey detections are based on acoustic cues
- Each sound provides clues to the identity of the caller, and the behavioral and ecological context
- Many biological phenomena can be heard at much greater ranges than they can be seen
- Acoustic data are one-dimensional, and *comparatively* easy to render or condense.

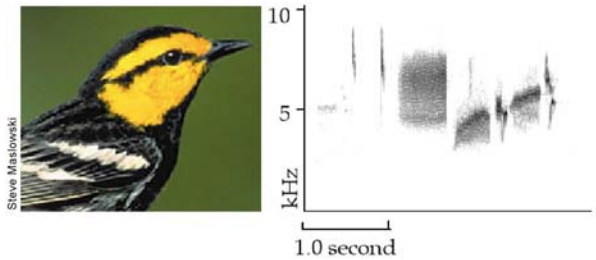
Environmental Acoustic Monitoring Tools

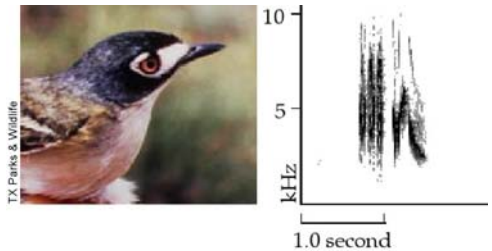
- **Programmable Digital Recorders:** monitor sites affording sporadic access, quantify patterns of singing activity, document correlations of breeding activity on intensive study areas
- **Free-Drifting Aerial Recorders:** monitor inacessible areas, conduct randomized line transect surveys free of “roadside bias”
- **Nocturnal Flight Call Detectors:** automatically detect and identify migrating birds by augmenting existing computers with specialized microphones and software
- **Array Recording and Localization:** map display perches to obtain an unbiased measure of territorial density; used in conjunction with rapid index methods (like point counts), this could provide a rigorous double sampling method for estimating population parameters
- **Signal Processing:** high-speed screening; automatic detection and classification of signals

SERDP CS-1185 Objectives



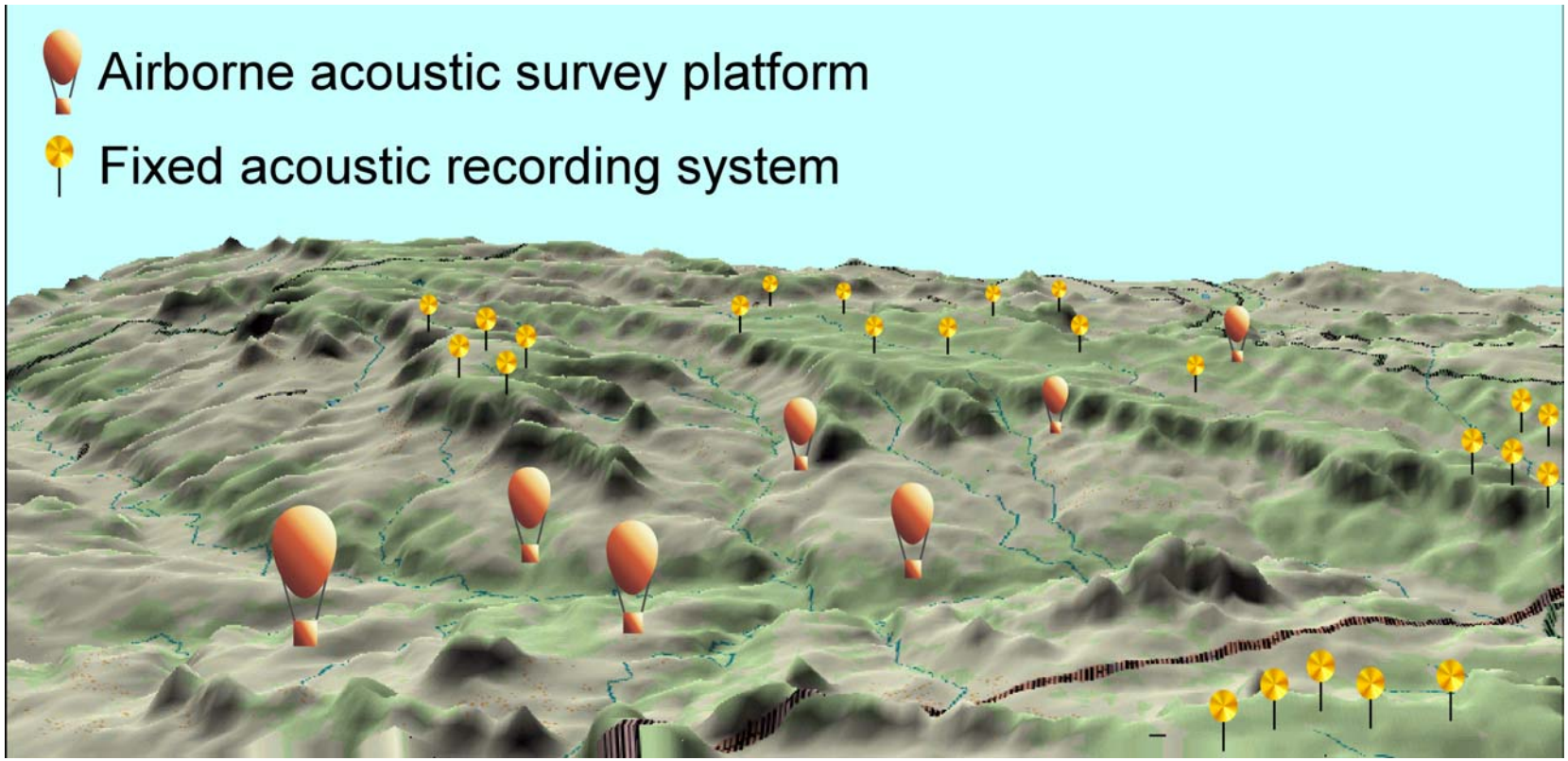






- Use Autonomous Recording System (ARS) to monitor Golden-cheeked Warbler (GCWA) and Black-capped Vireo (BCVI) at infrequently accessible sites
- Develop small aerial system for monitoring permanently or frequently inaccessible sites, including 25,000 ha live-fire area
- Investigate methodology of acoustical monitoring for population estimation

Distributed Sensor Network



Large areas and sporadic singing recommend a distributed sensor network

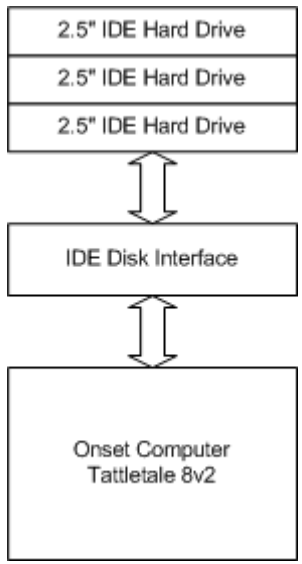
Autonomous Recording Units

- Enable short- or long-term unattended monitoring at a fixed location
- Can easily detect species that vocalize too infrequently to be monitored effectively using point counts
- Can be deployed in advance at many sites and programmed to record simultaneously, producing true matched samples
- Useful for documenting variation in calling activity to improve accuracy of all acoustic censuses and the value of historical data sets
- Hundreds to thousands of hours of recordings per deployment – automated processing is required

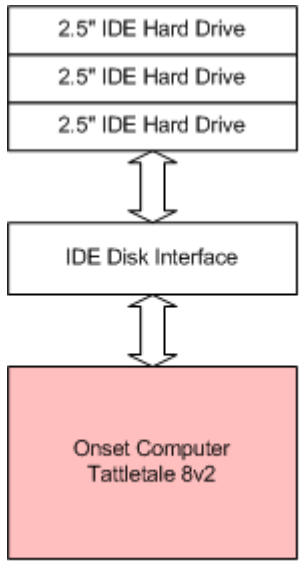
Free-Drifting Balloon Platform

- Provides a significant advance in field sampling methods
- Provides data in traditionally inaccessible habitats, e.g. impact areas
- Can be used to estimate local densities of acoustically active bird species along the flight path
- Small, economical, silent, wind-free
- 2-microphone vertical line array yields distance of sound from point on ground directly beneath balloon
- Individual birds can be located (subject to left/right ambiguity) if multiple calls detected while the individual is stationary
- Maps of song detections will provide critical data for models that explain and predict migratory landbird densities

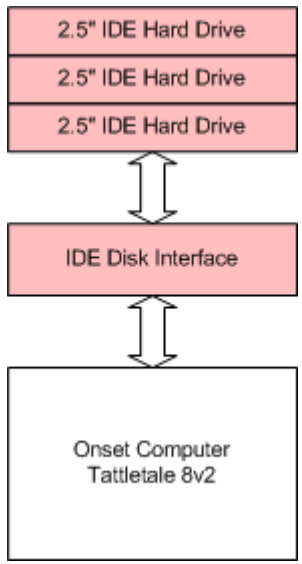
System Block Diagrams



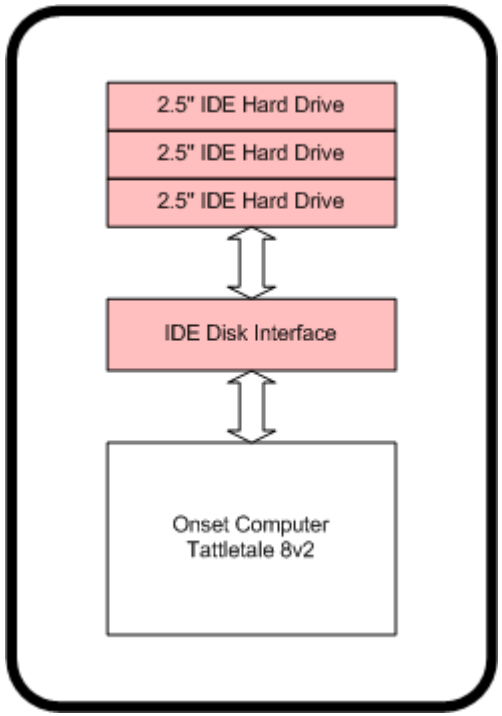
Microcontroller Module



IDE Drive Interface



Data Storage Module



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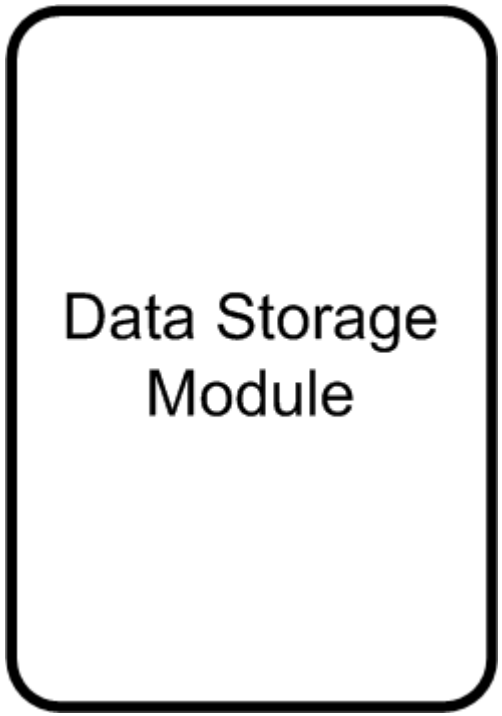

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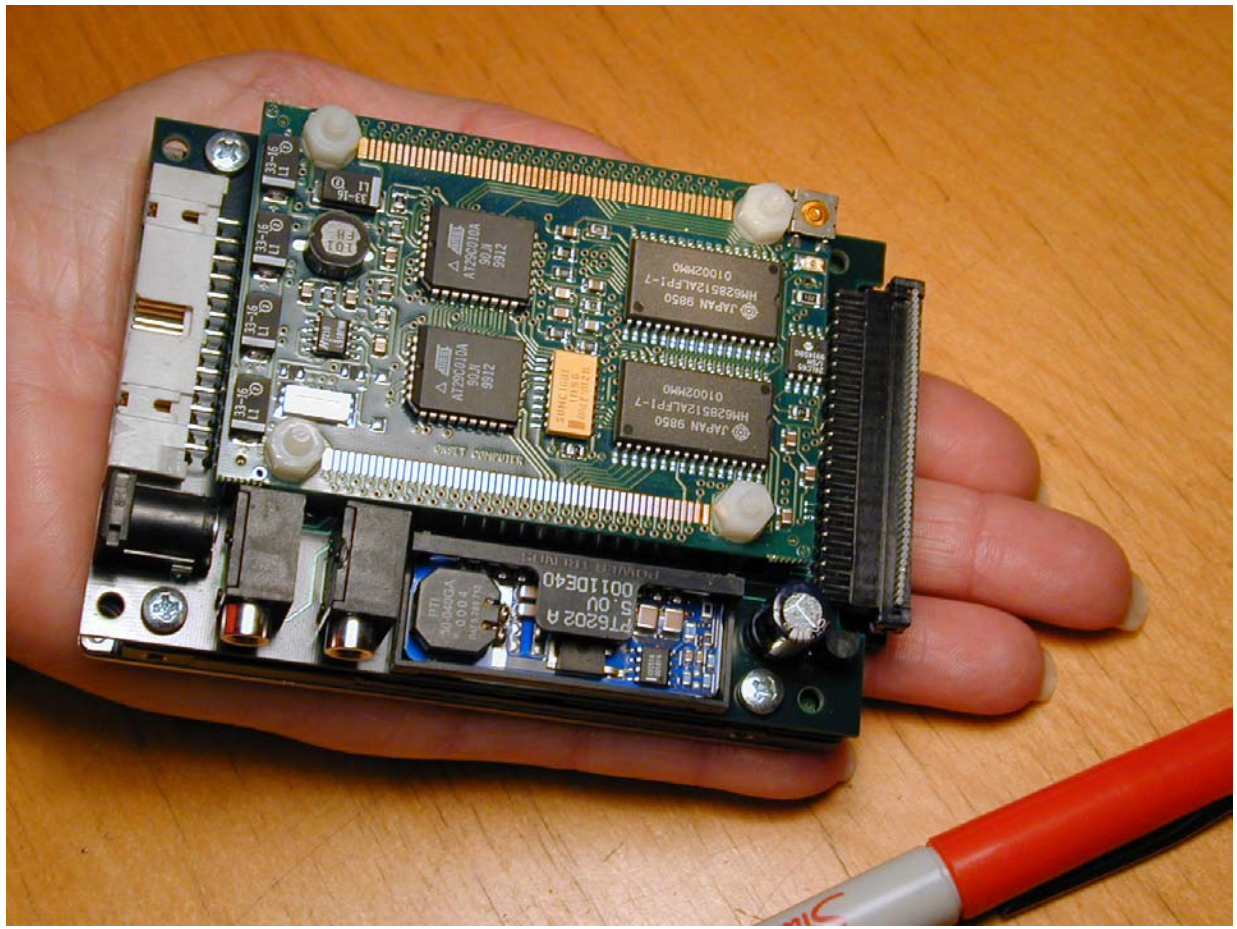


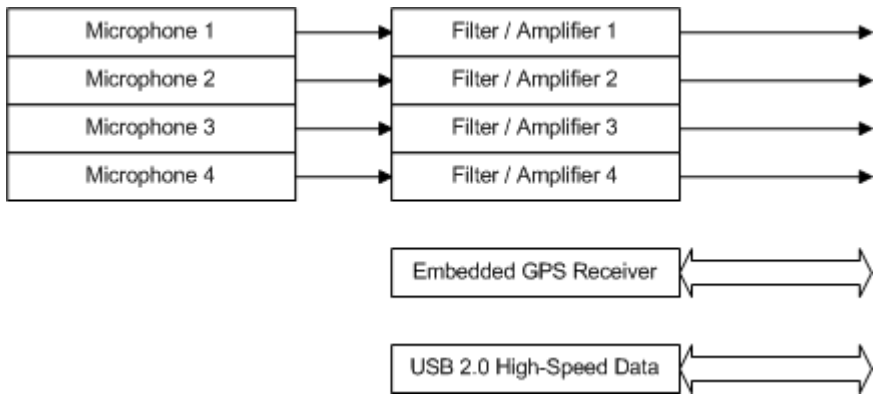
Data Storage Module

Data Storage Module

- 12-bit sample resolution, up to 64 kHz sampling rate
- Support for up to 4 channels of data
- Up to 100 GB of data storage on a 2.5” hard drive
- Programmable sampling schedule and parameters
- Embedded software to interface with add-ons as well as the outside world

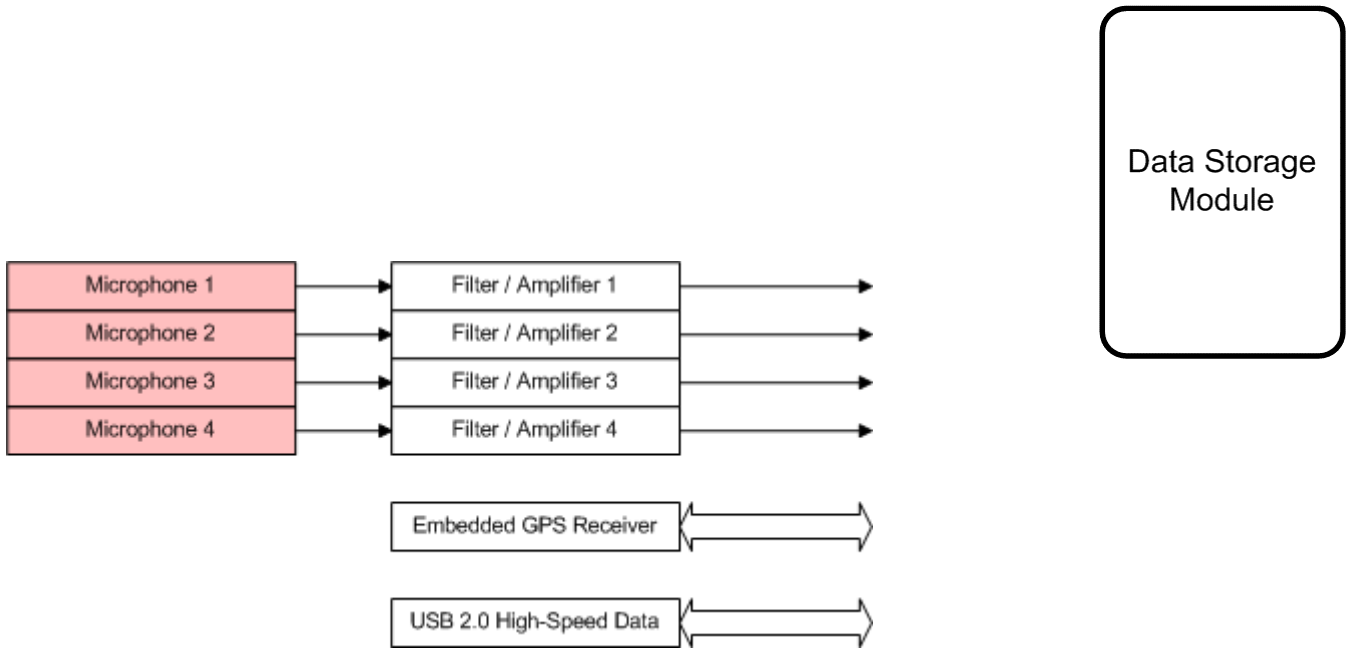
Data Storage Module

ARU Components

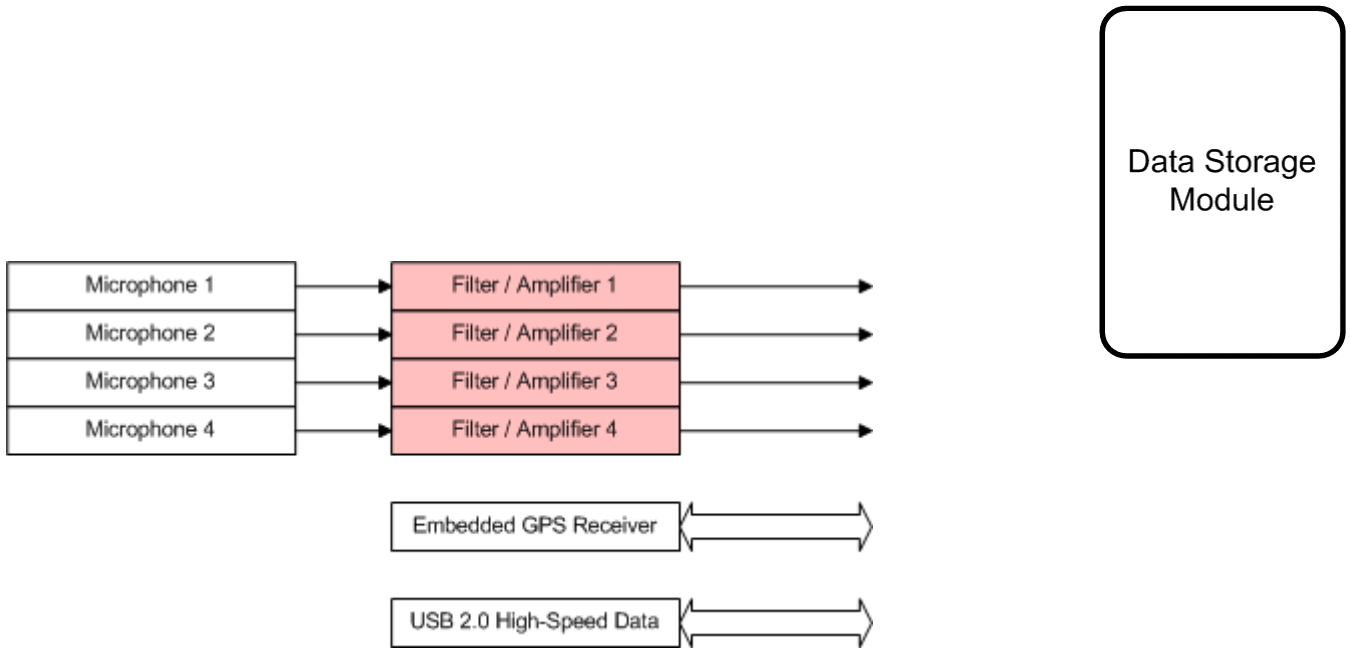


Data Storage Module

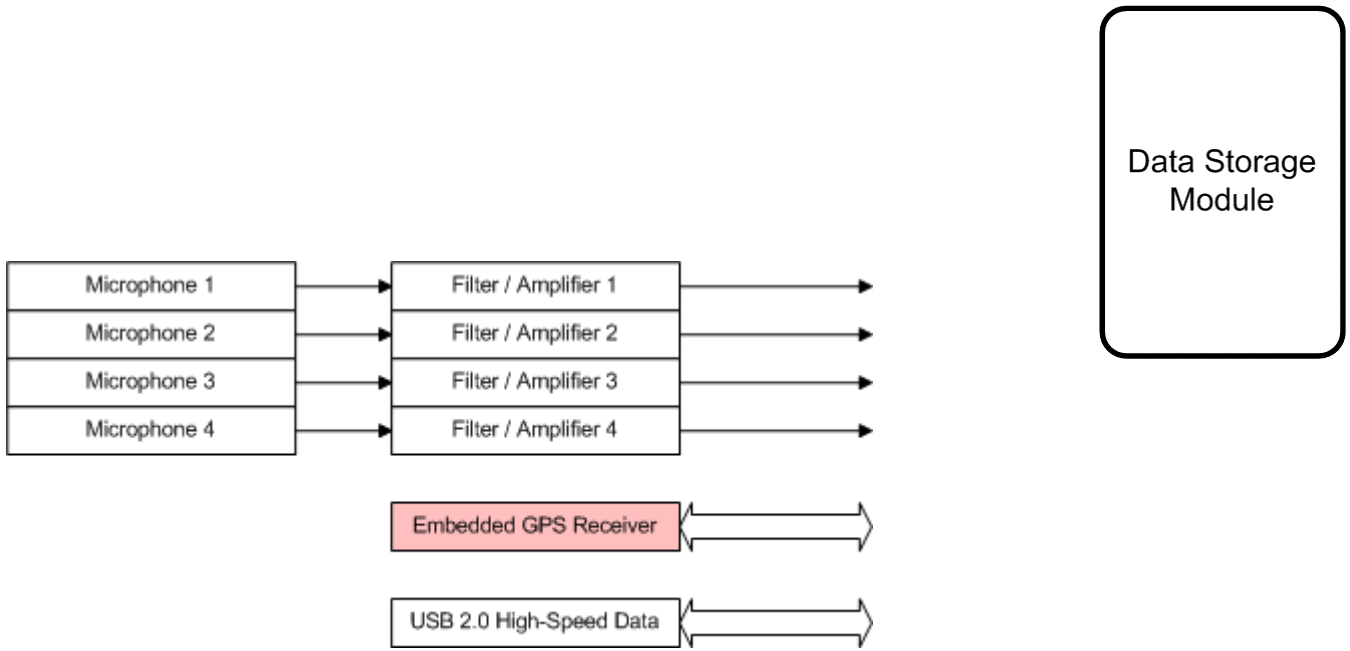
Electret Condenser Microphones



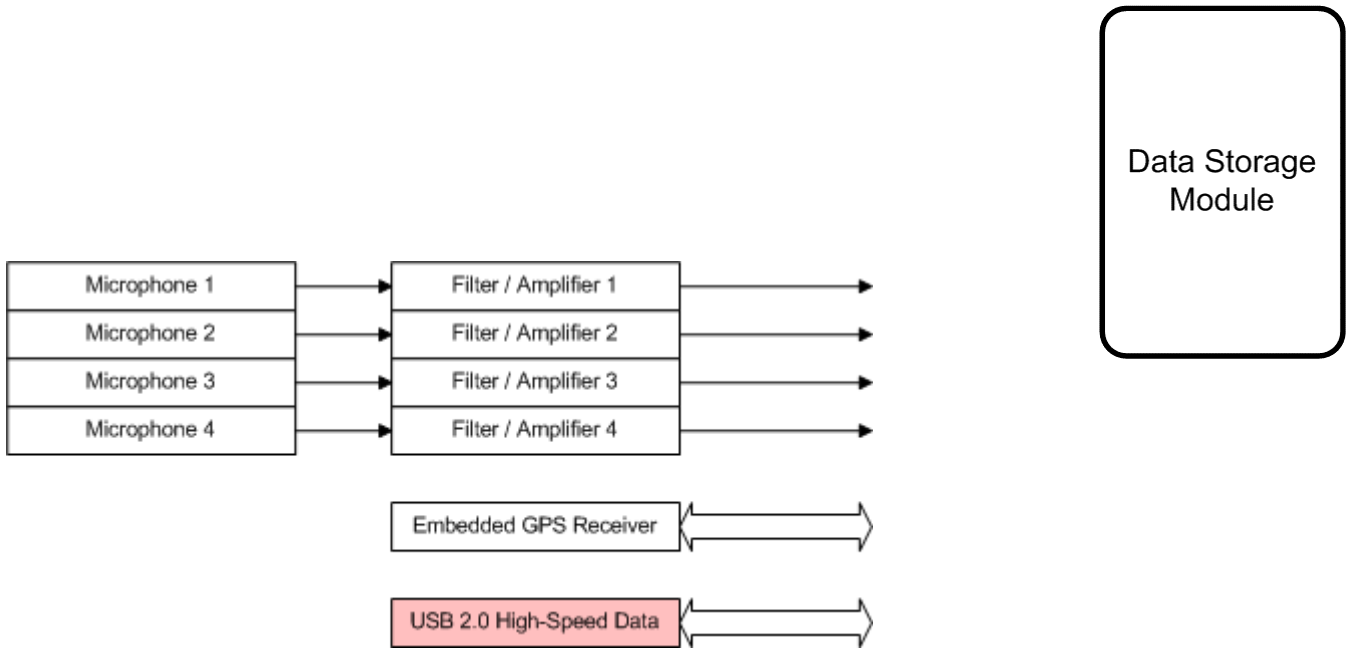
Fixed Filter, Variable Gain Amp



GPS Receiver for Precise Timing



USB 2.0 Data Offload Capability



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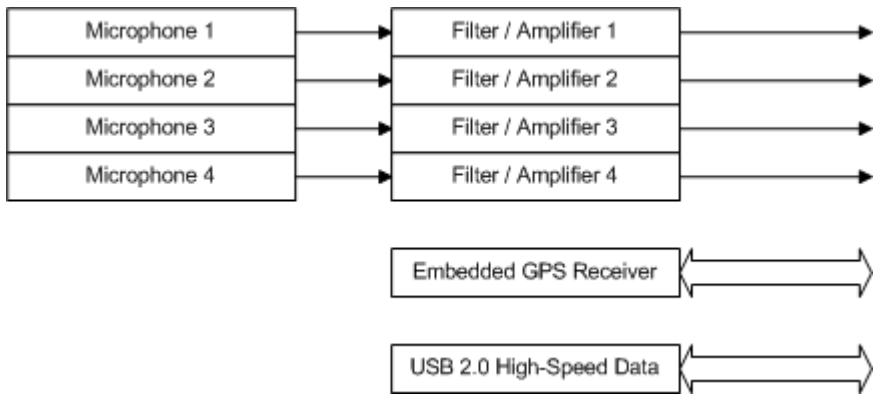

Data Storage Module

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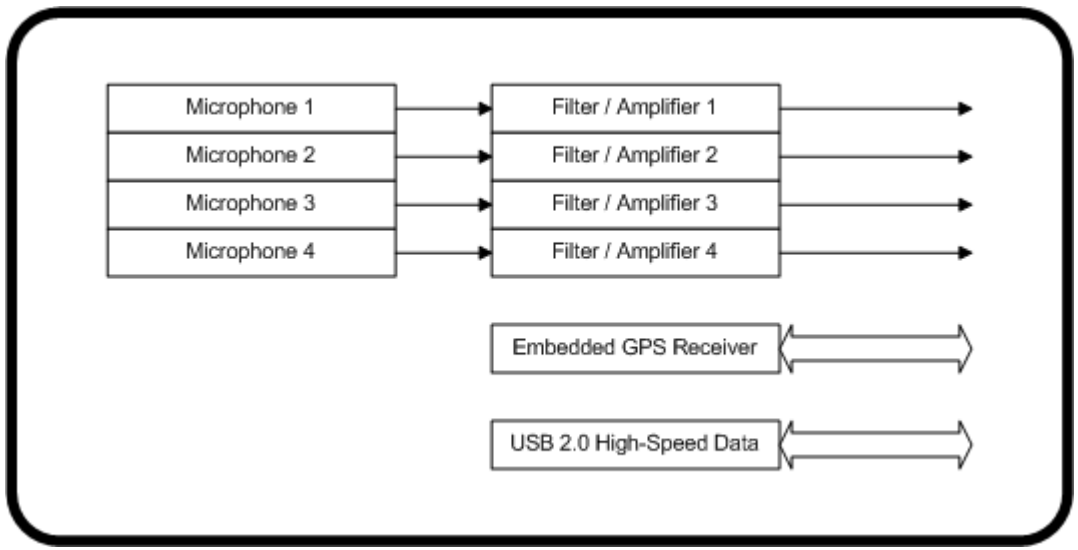

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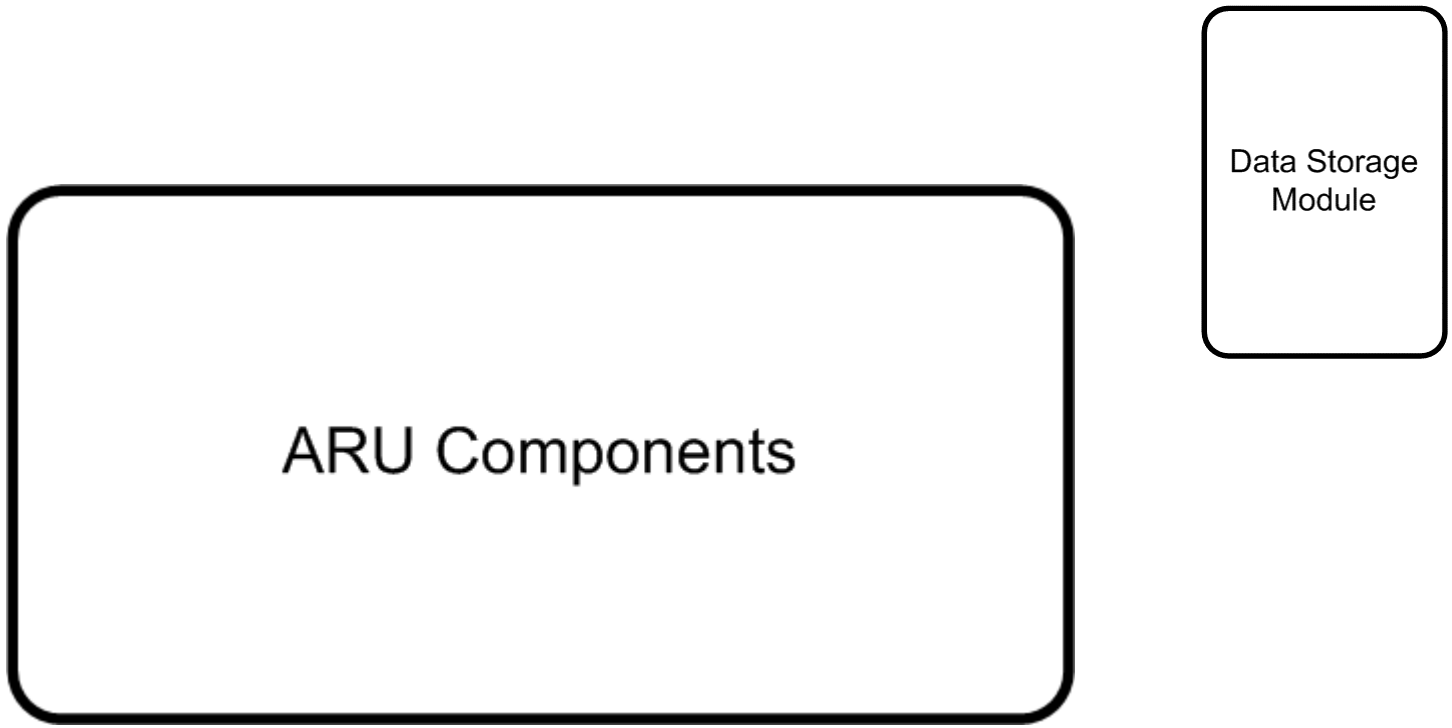

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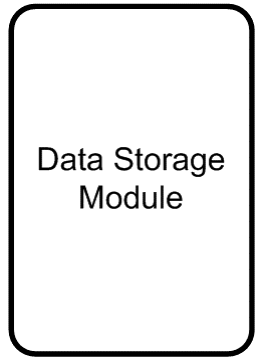
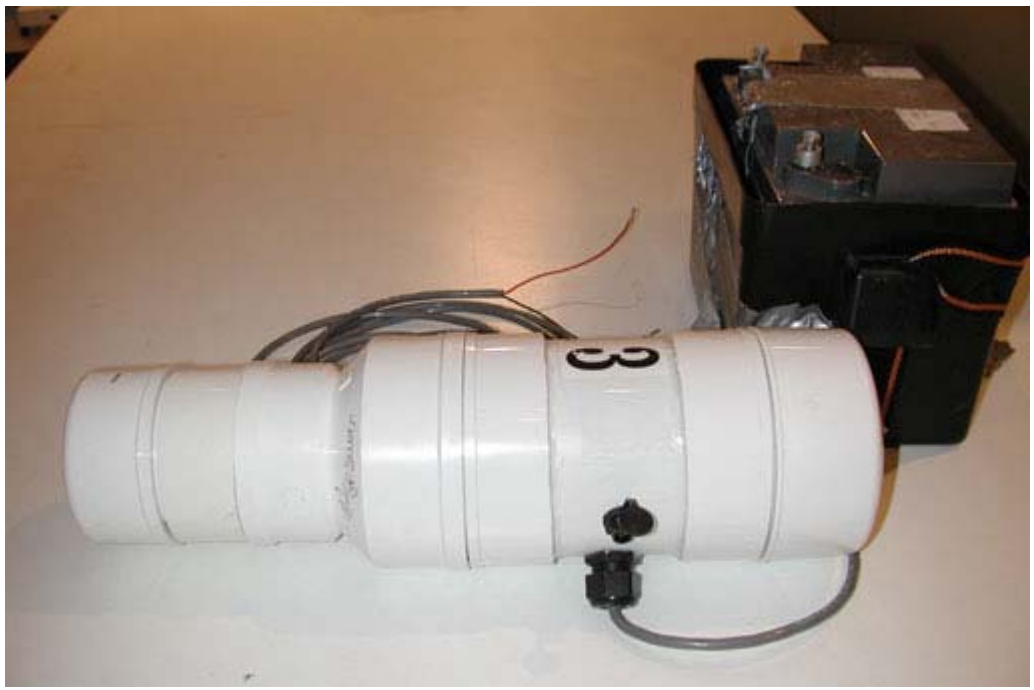


- Low-cost PVC housing (now extruded Al)
- Battery can be sized to fit any recording needs
- Single microphone systems in one package
- Multiple microphone systems have pods

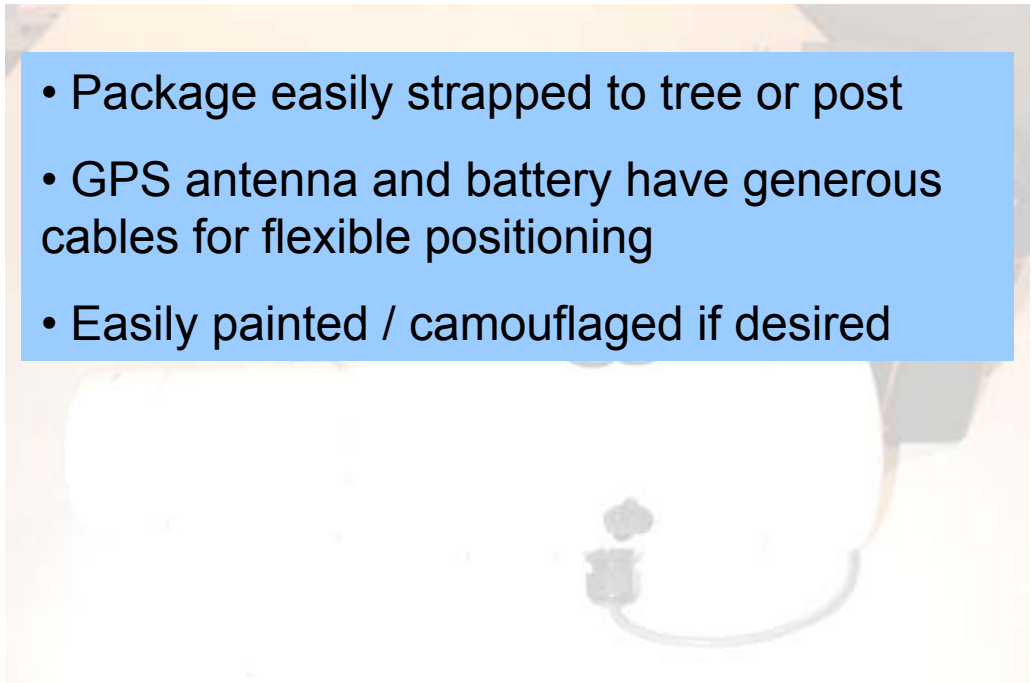
ARU



Data Storage Module

ARU Components

ARU



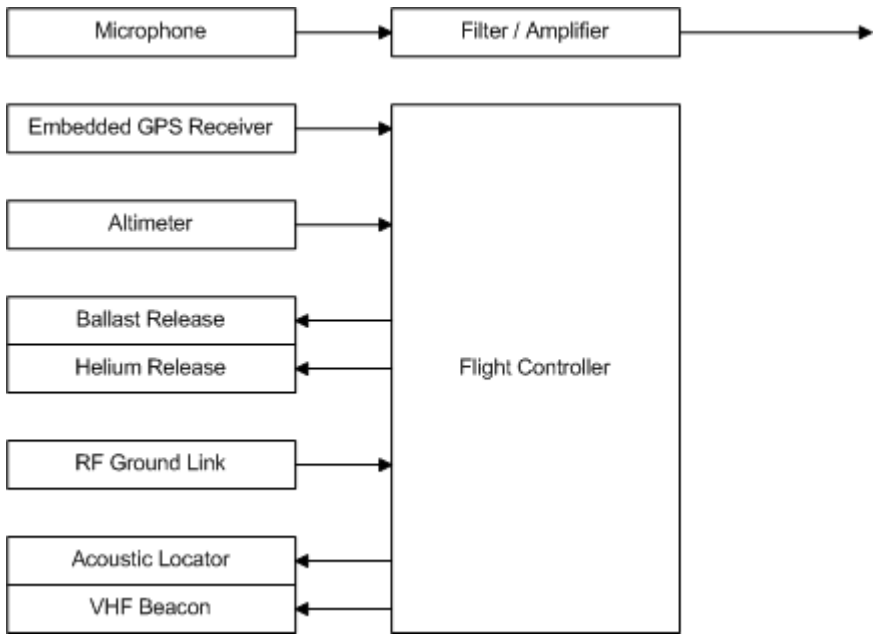
- Package easily strapped to tree or post
- GPS antenna and battery have generous cables for flexible positioning
- Easily painted / camouflaged if desired

Data Storage Module

ARU Components

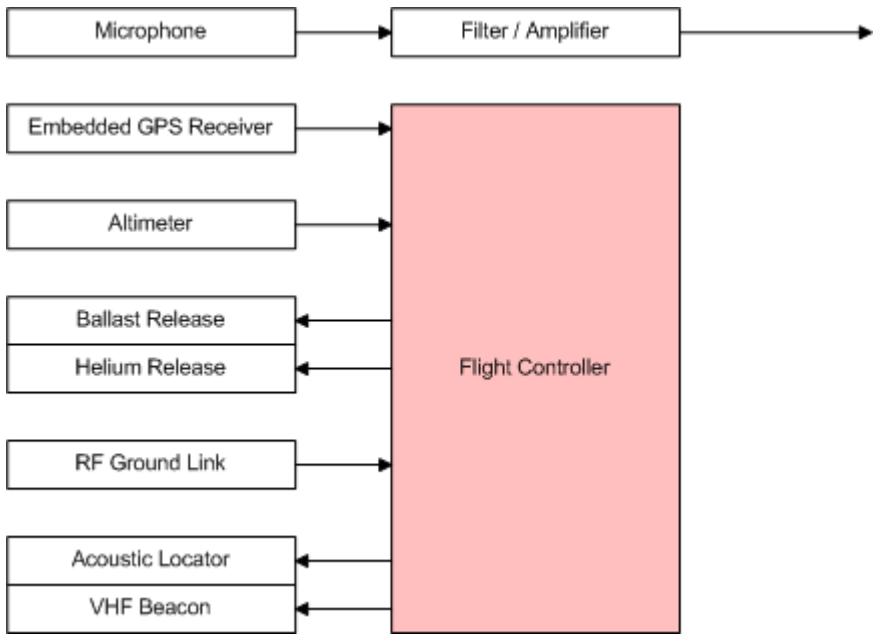
Data Storage Module

Balloon Components



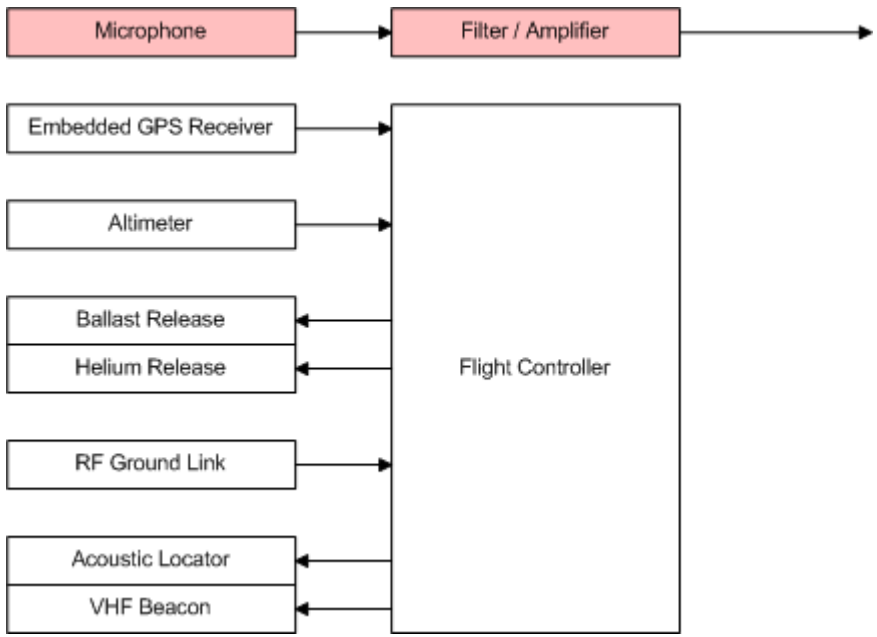
Data Storage Module

TI MSP430F149 Flight Controller



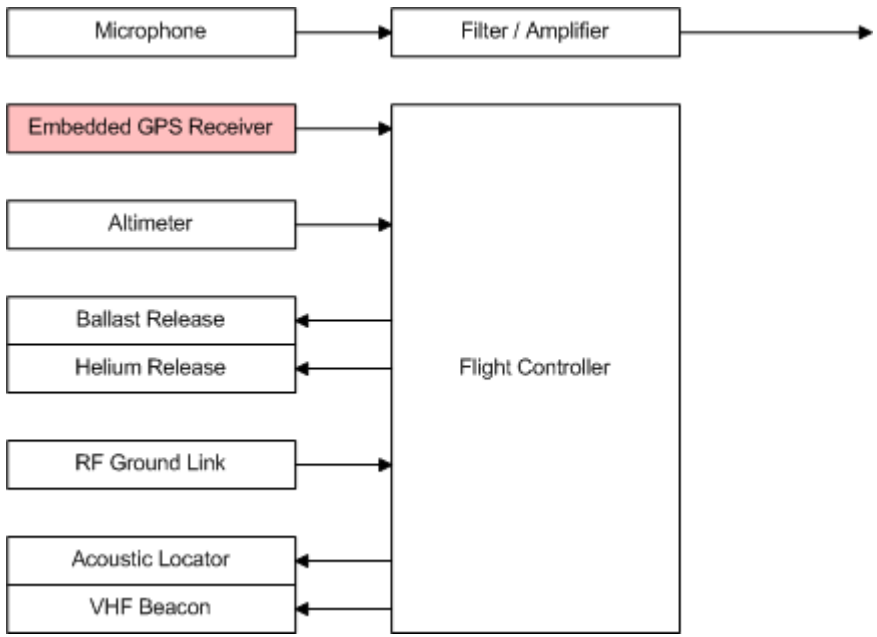
Data Storage Module

Electret / Horn and Filter / Amp



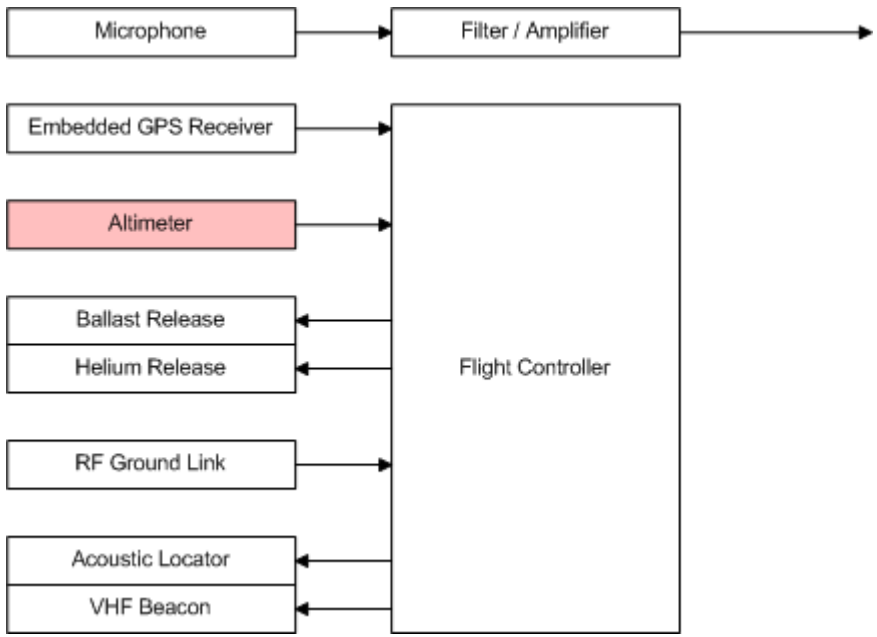
Data Storage Module

GPS Receiver for Positioning



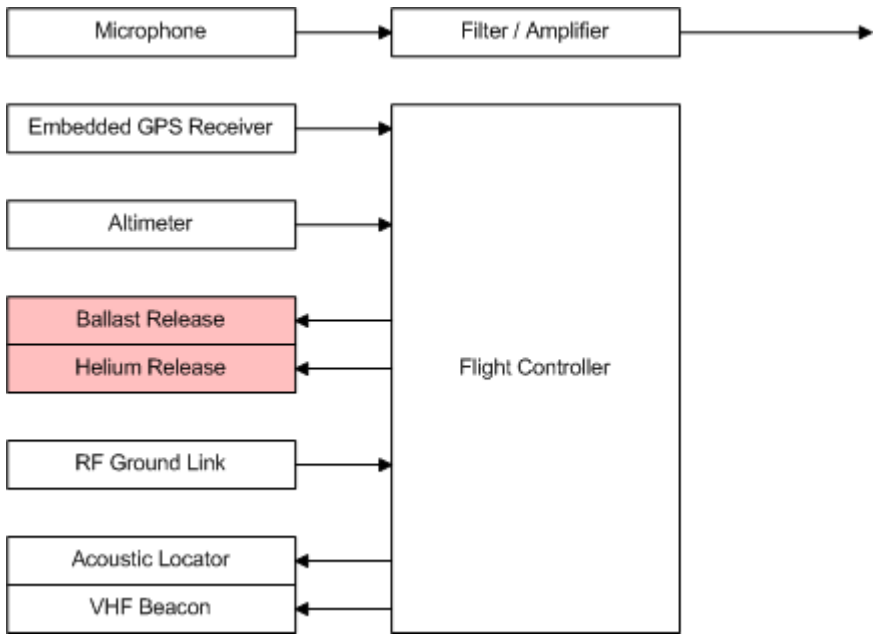
Data Storage Module

Altimeter for Position Enhancement



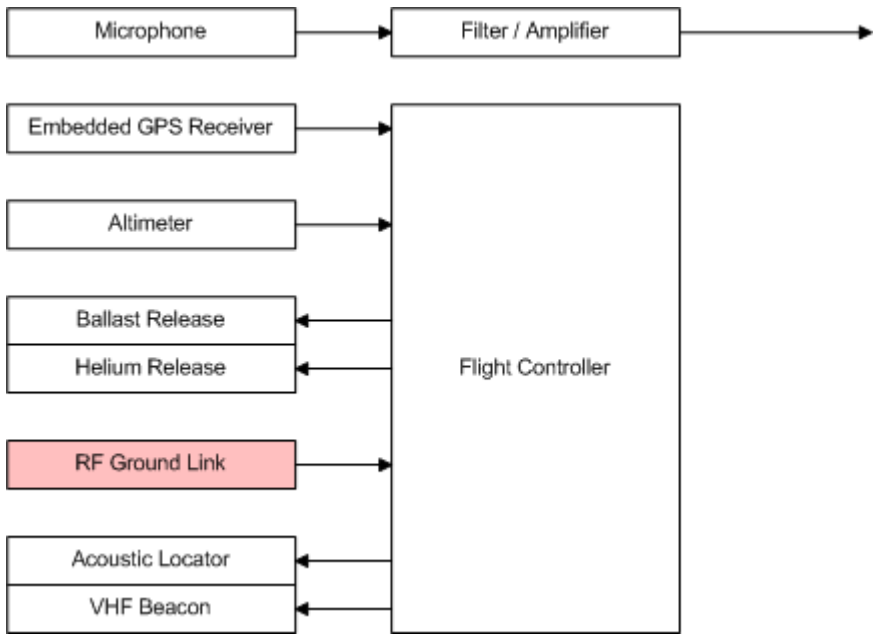
Data Storage Module

Altitude Control



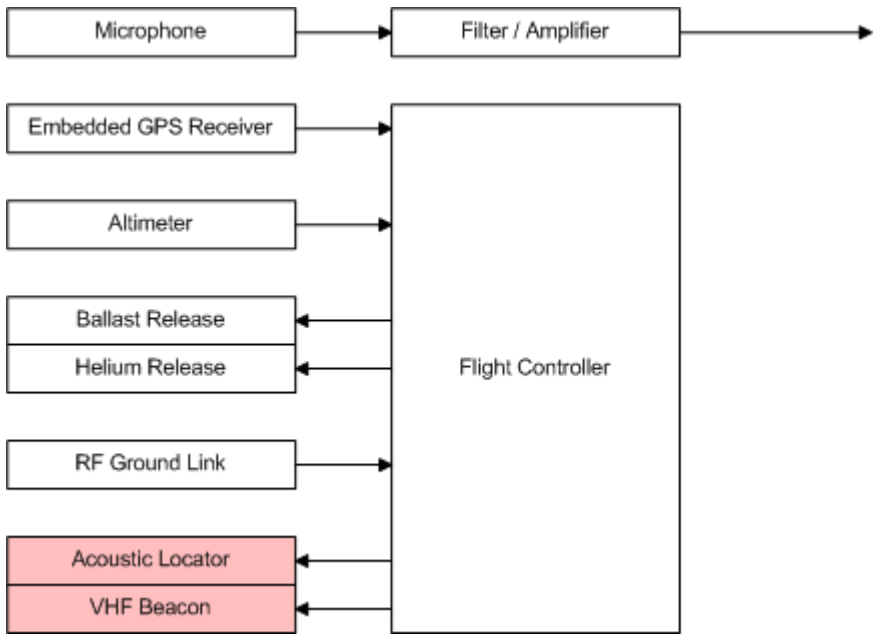
Data Storage Module

Radio Control Ground Link



Data Storage Module

Location Aids



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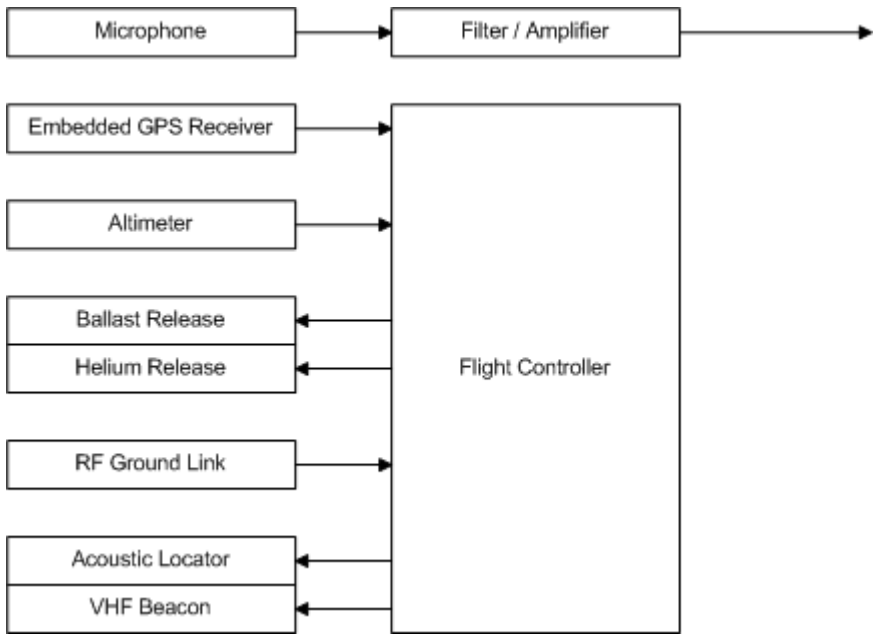
Balloon Components



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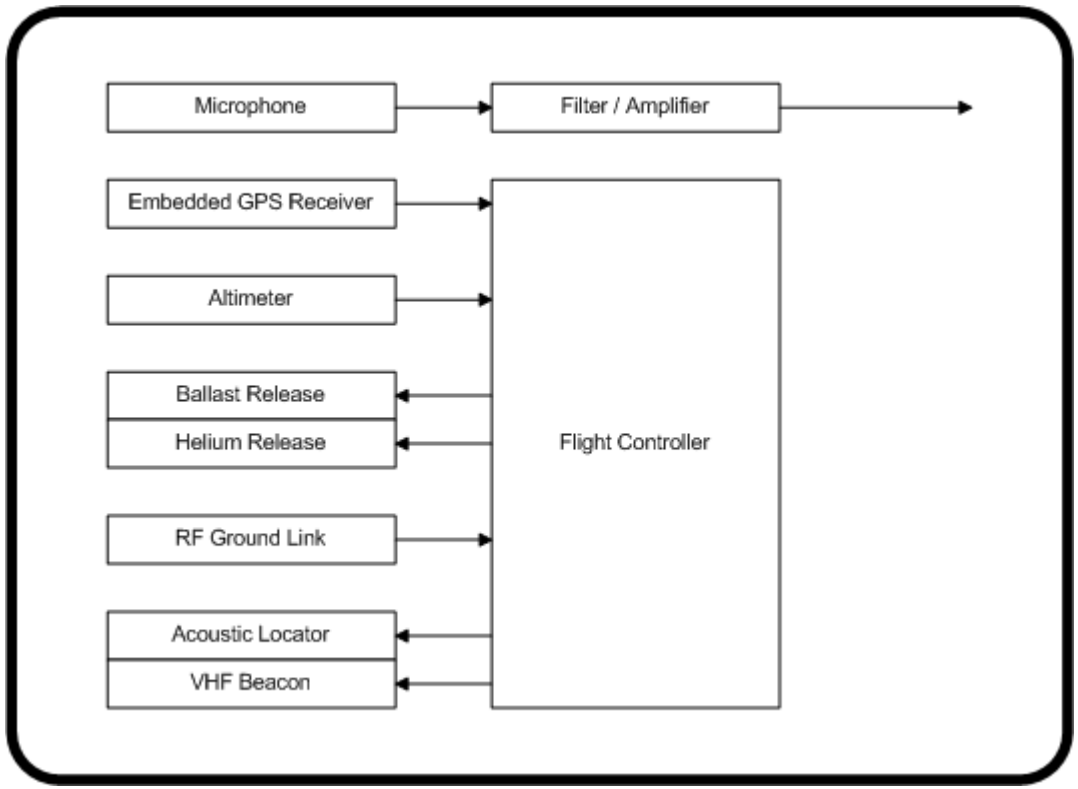

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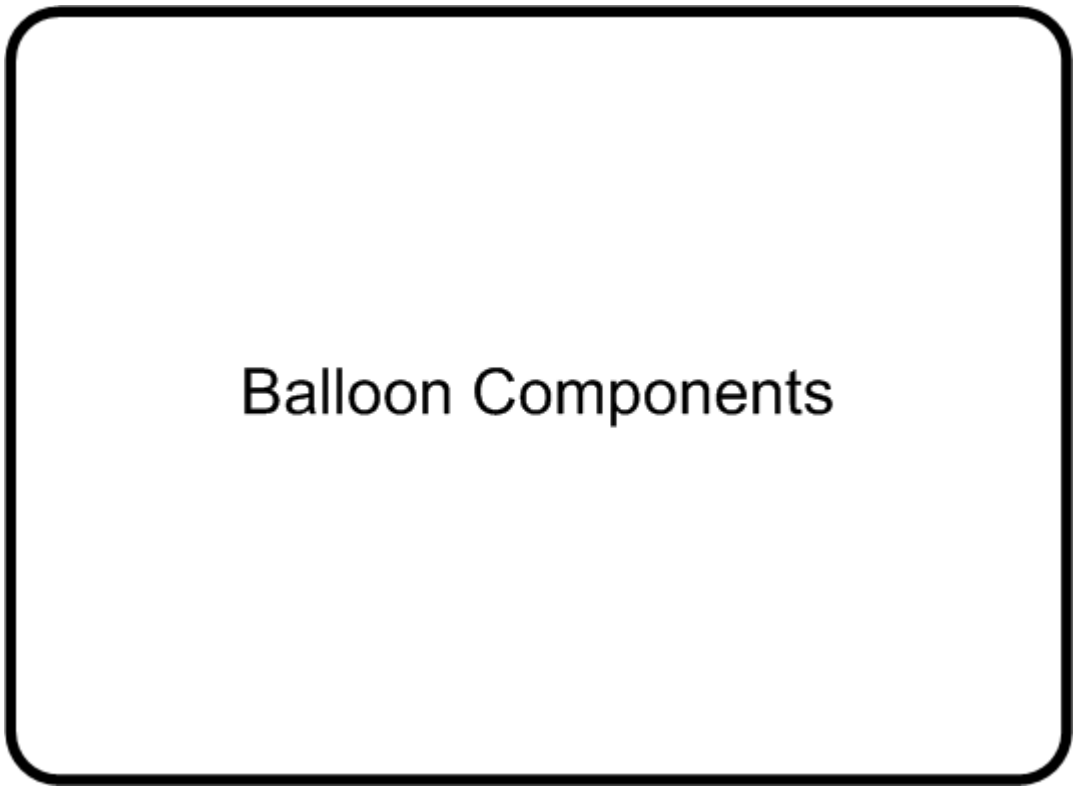
Balloon Components



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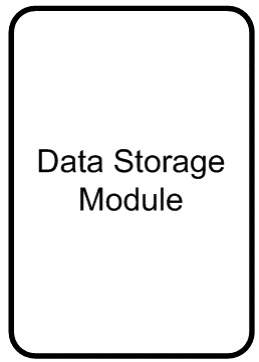
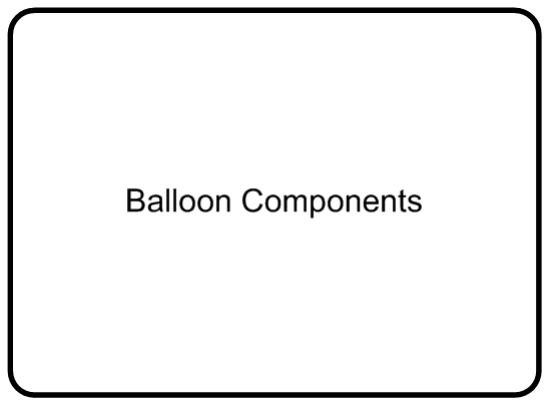
Balloon Components



- Radio link allows real-time position tracking, system control
- User-specified flight control parameters
- 2-channel recording with VLA



Balloon

Data Storage Module

Balloon Components

Balloon

- Relaxed FAA flight safety requirements for payloads of this weight (< 4 lb)
- Low-noise platform – no apparent wind
- Balloon flights of up to a few hours possible

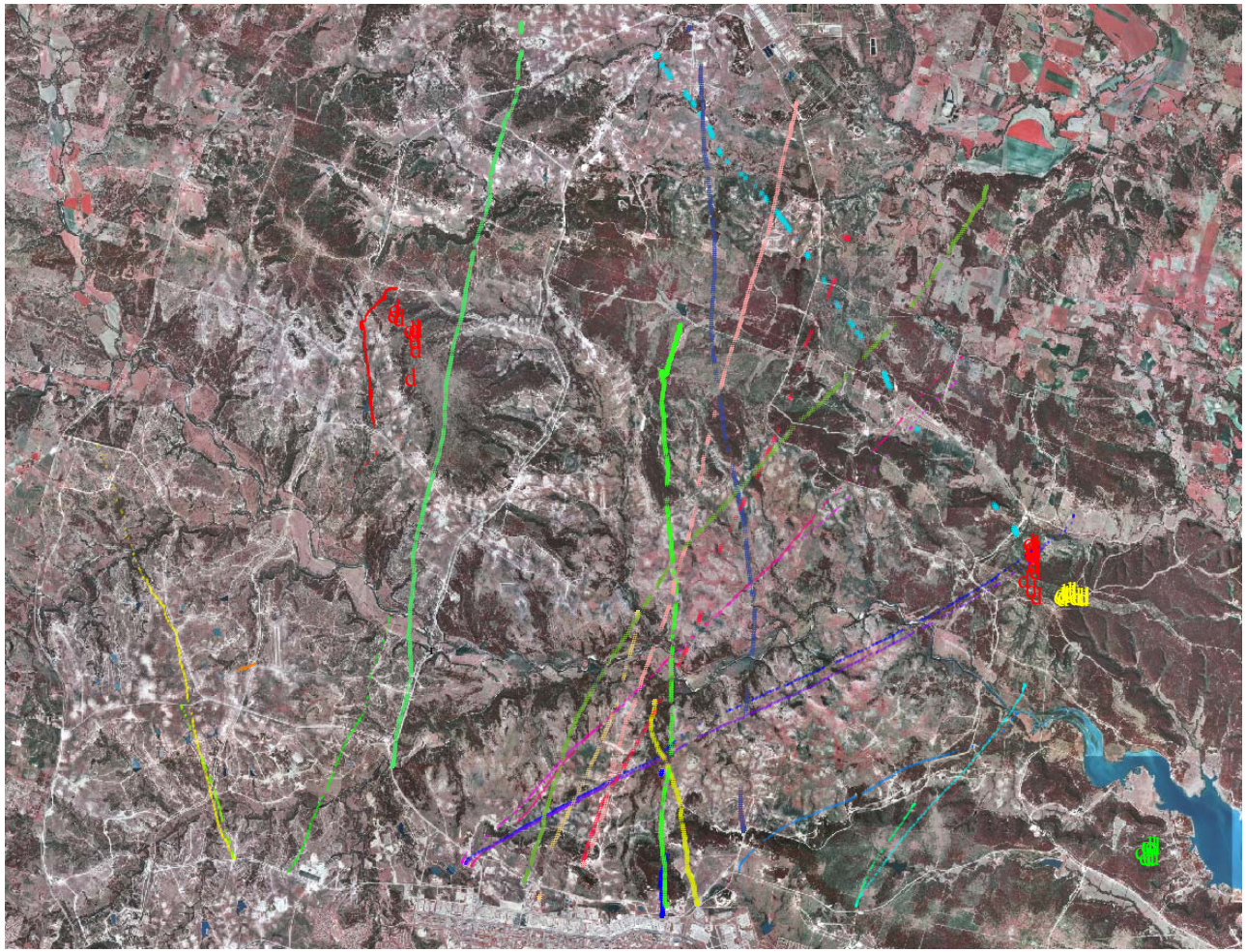
Data Storage Module

Balloon Components

Images from the Field

Images from the Field

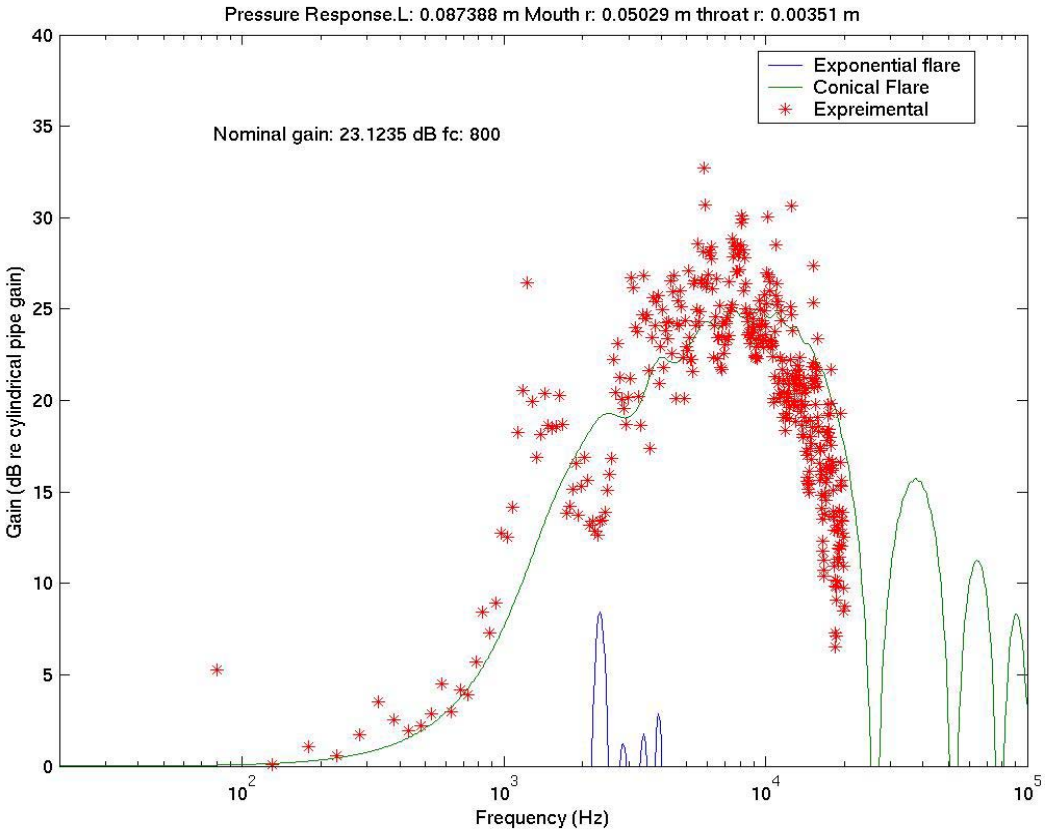
Fort Hood, TX ARUs and Balloons



Nocturnal Flight Calls (NFC)

- Many migratory birds undertake their long-distance flights primarily or entirely at night, with a large proportion vocalizing while migrating
- Many NFCs are uniquely identifiable to a particular species, others to one of a “species complex”
- NFCs of most species are both highly stereotyped and structurally distinct from those of other species
- Detection rates at sunrise and sunset used to monitor stopover use of land by vocally active nocturnal migrants
- Flight calls have been detected at altitudes in excess of 250 m for sparrows and warblers, and in excess of 700 m for thrushes; horn-loaded microphones can significantly extend this range

Horn-Loading Systems

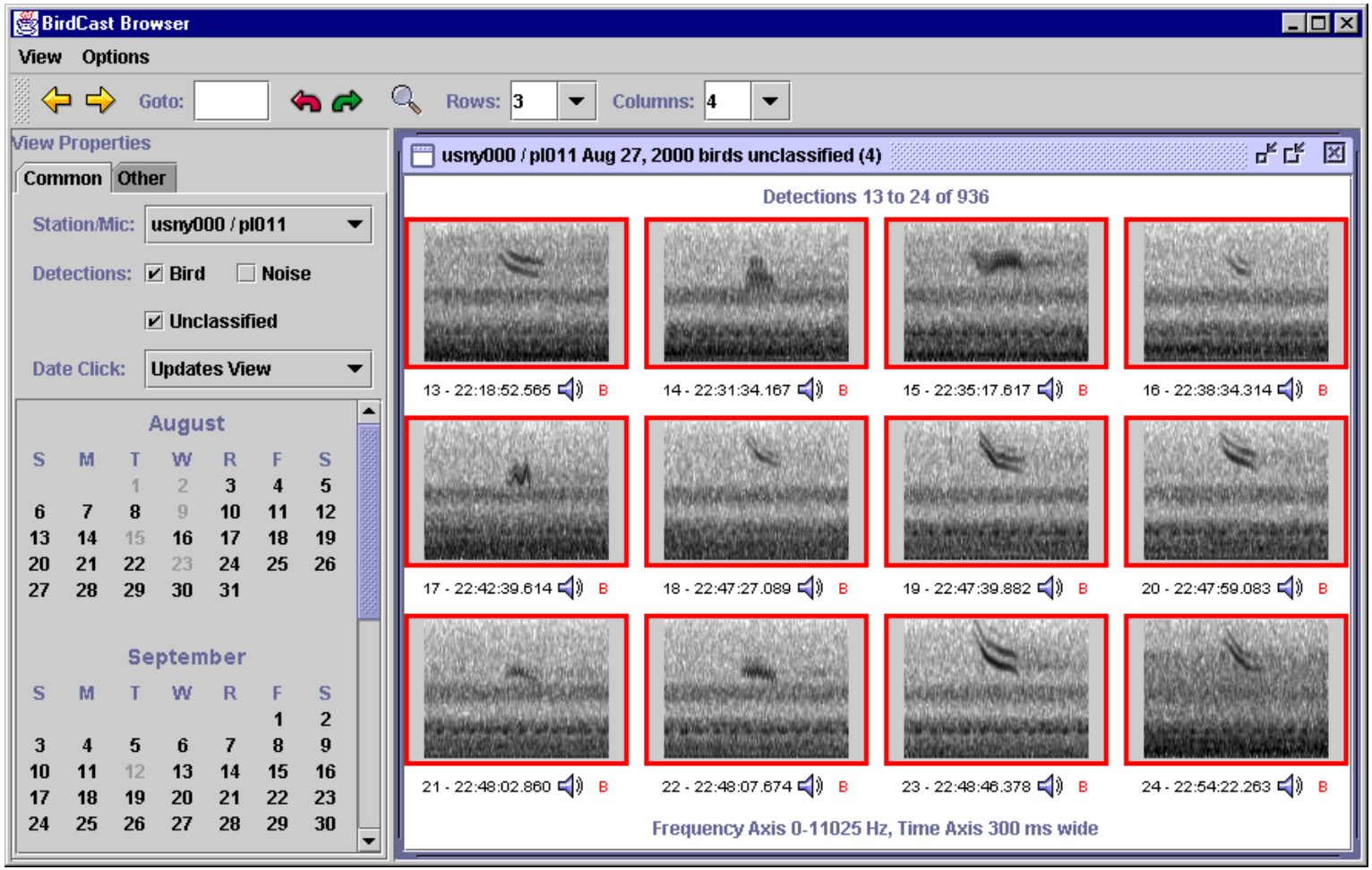


Analytical methods enabled design of effective horn-loading systems that achieve significant gain while retaining reasonable recording aperture

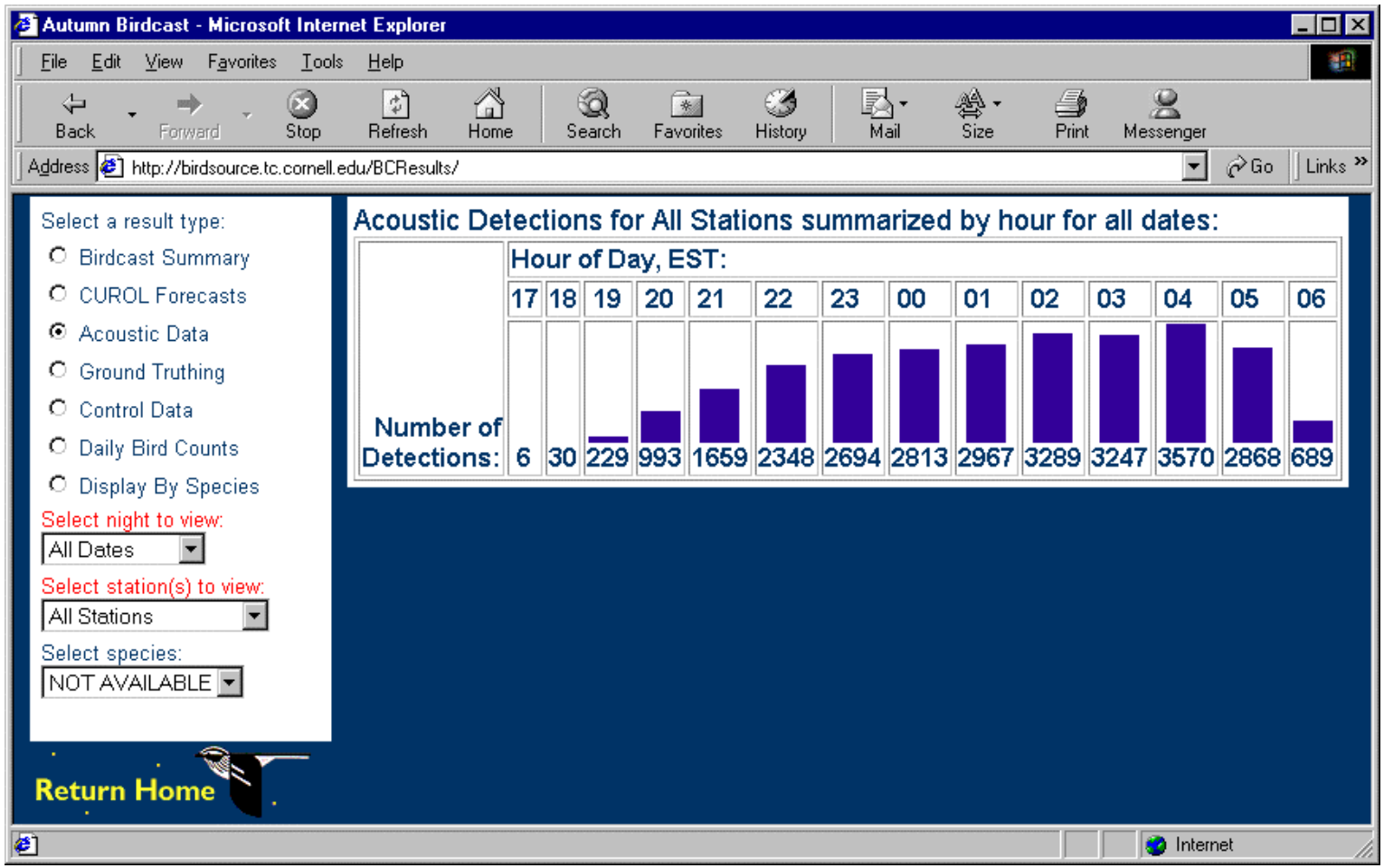
Birdcast: A Prototype

- Simultaneous radar, visual, and acoustical monitoring of bird migration through the Delaware river valley and Ithaca, NY
- Spring and Fall 2000
- 9 monitoring stations equipped with microphone and detector system
- Data collection over the internet; detections uploaded to server each morning
- 27,000 warbler and sparrow calls in fall
- Minimal cost of equipment required (< $100 per station + volunteered host computer) and scalability of server operations could allow continent-wide NFC monitoring

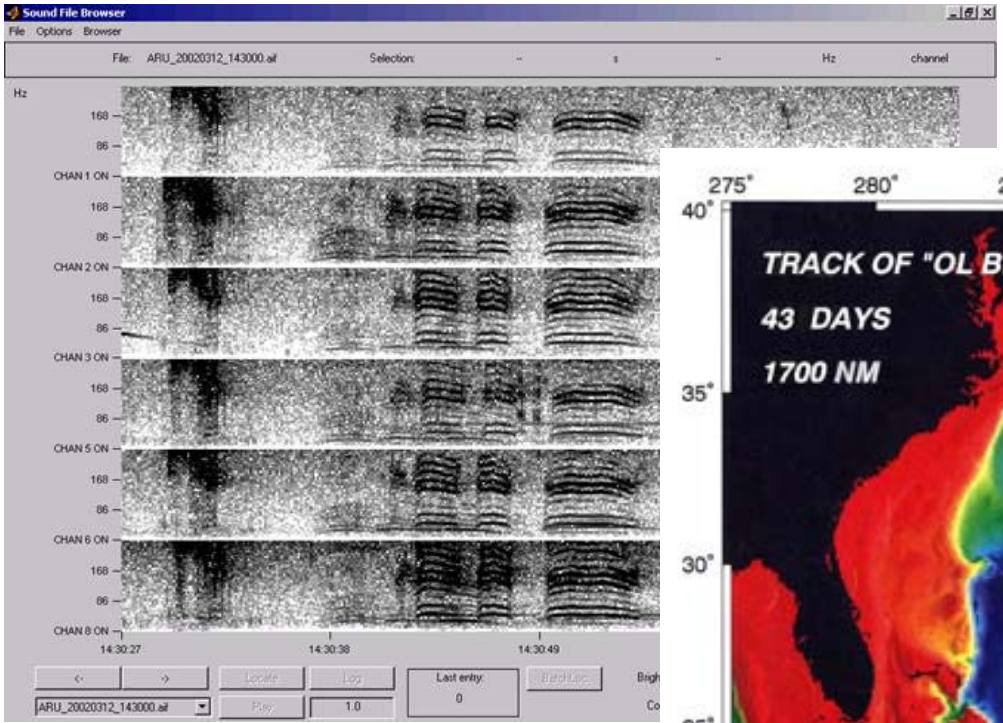
Web Browser Interface

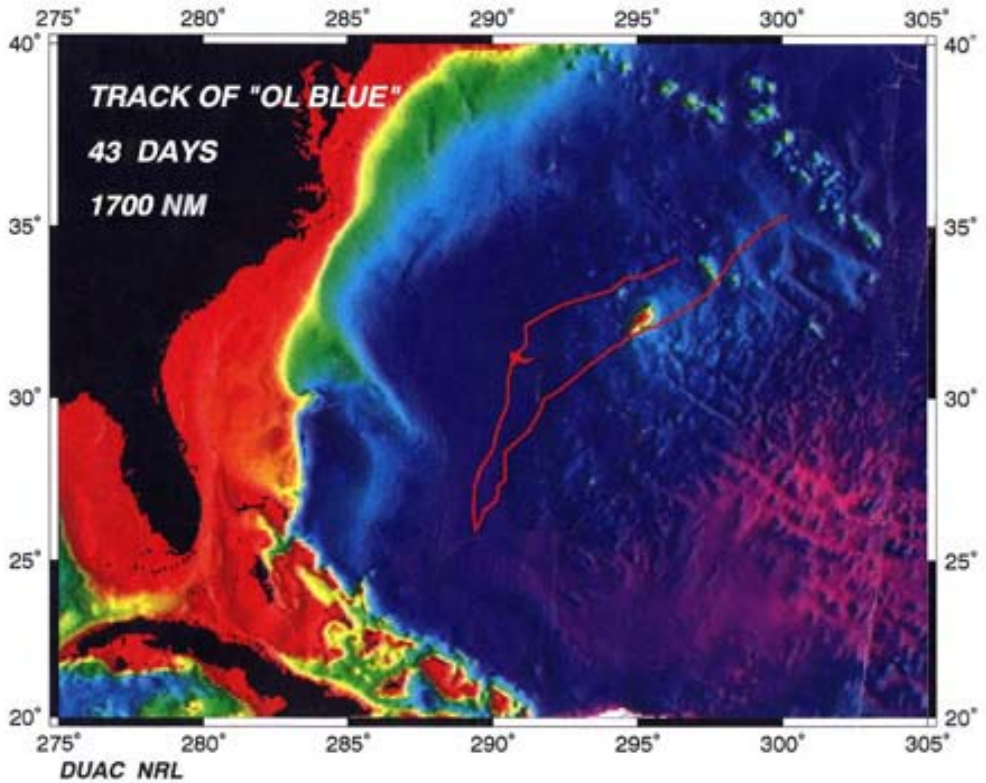


Results

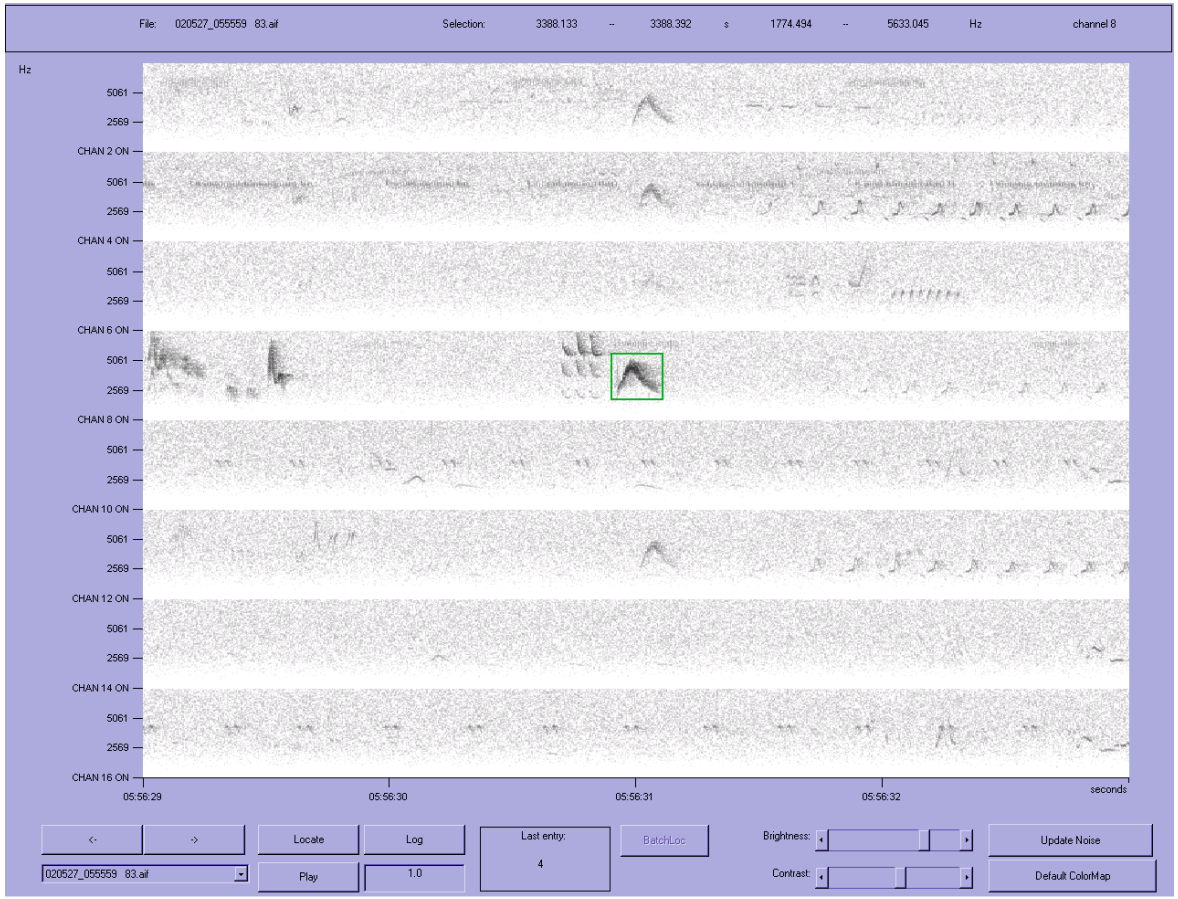

Autumn Birdcast - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Size Print Messenger
Address http://birdsource.tc.cornell.edu/BCResults/
Go Links
Select a result type:
Birdcast Summary
CUROL Forecasts
Acoustic Data
Ground Truthing
Control Data
Daily Bird Counts
Display By Species
Select night to view:
All Dates
Select station(s) to view:
All Stations
Select species:
NOT AVAILABLE
Return Home
Acoustic Detections for All Stations summarized by hour for all dates:
Hour of Day, EST:
17 18 19 20 21 22 23 00 01 02 03 04 05 06
Number of Detections:
6 30 229 993 1659 2348 2694 2813 2967 3289 3247 3570 2868 689
Internet

Localization



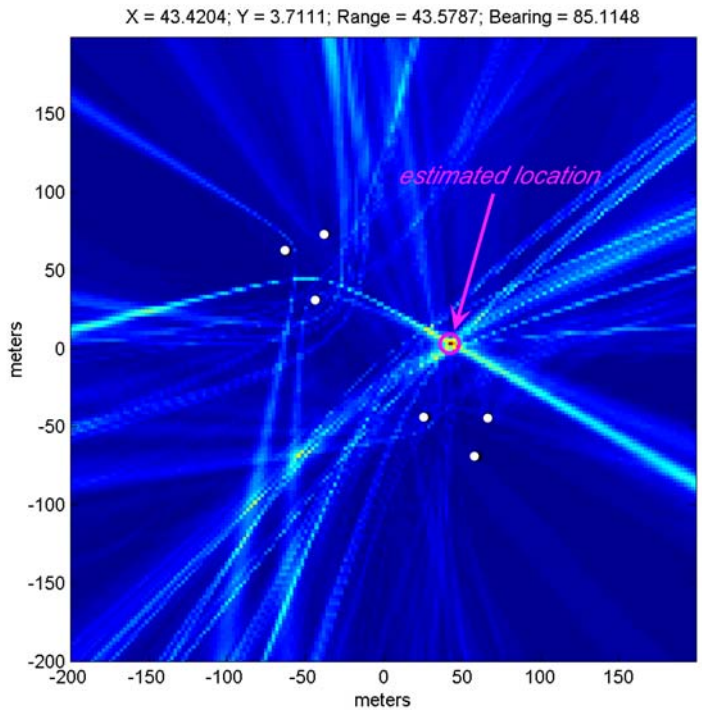


Localization



Typical multichannel spectrogram; user boxes signal of interest to locate

Signal Localization

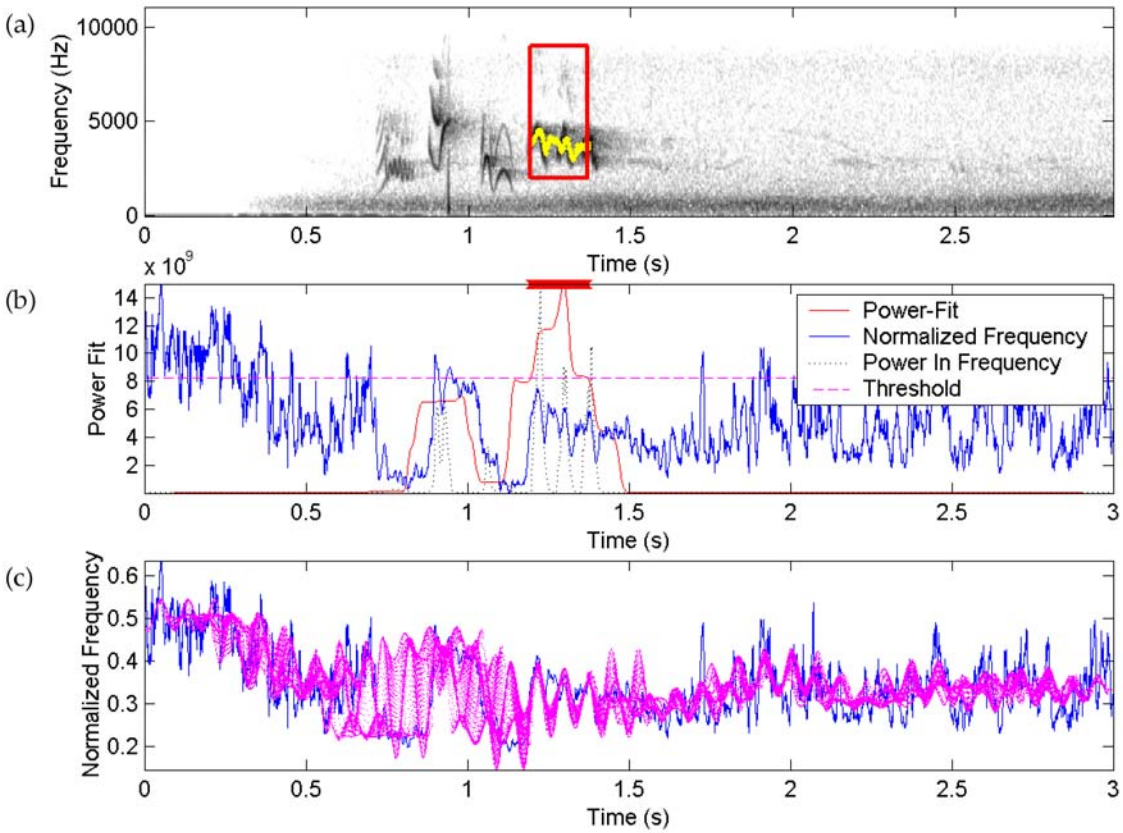


Probability surface for acoustic location of a frequency-modulated calibration whistle on the acoustic array used at Fort Hood in April 2001. Color indicates probability that the sound source was located at each point (blue = low, red = high). The six microphone positions are indicated by white dots. The location estimated by the acoustic algorithm is 5.5 m from the location determined by GPS.

Signal Detection and Classification

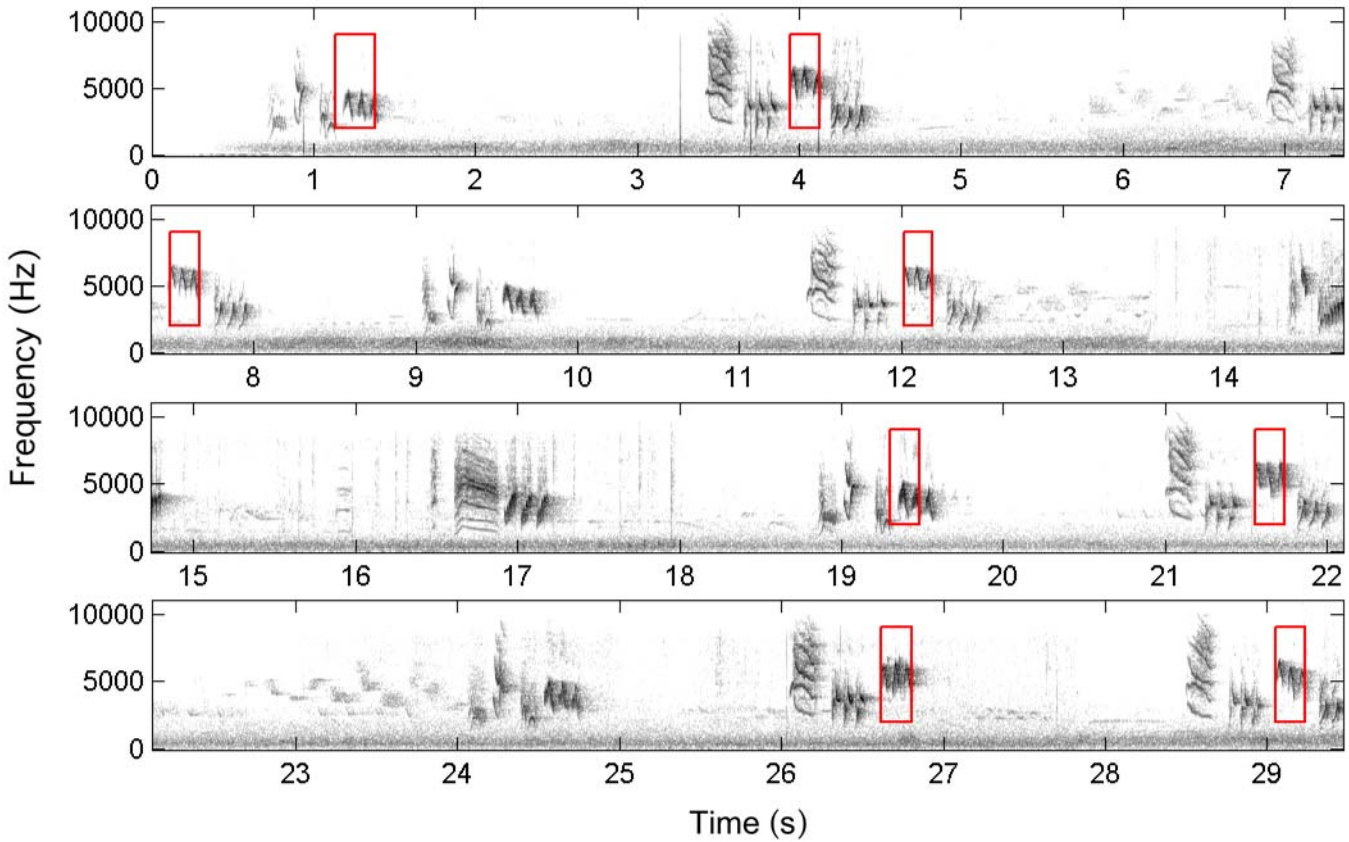
- A wide variety of techniques are in use to accomplish these tasks
- Speed, ease of implementation, and reliability are all important factors – often at odds with one another
- BRP is investing heavily in detector and classifier development
- Rapid prototyping environment – XBAT (Matlab-based)
- Deployment environment – Raven plug-ins

Signal Detection



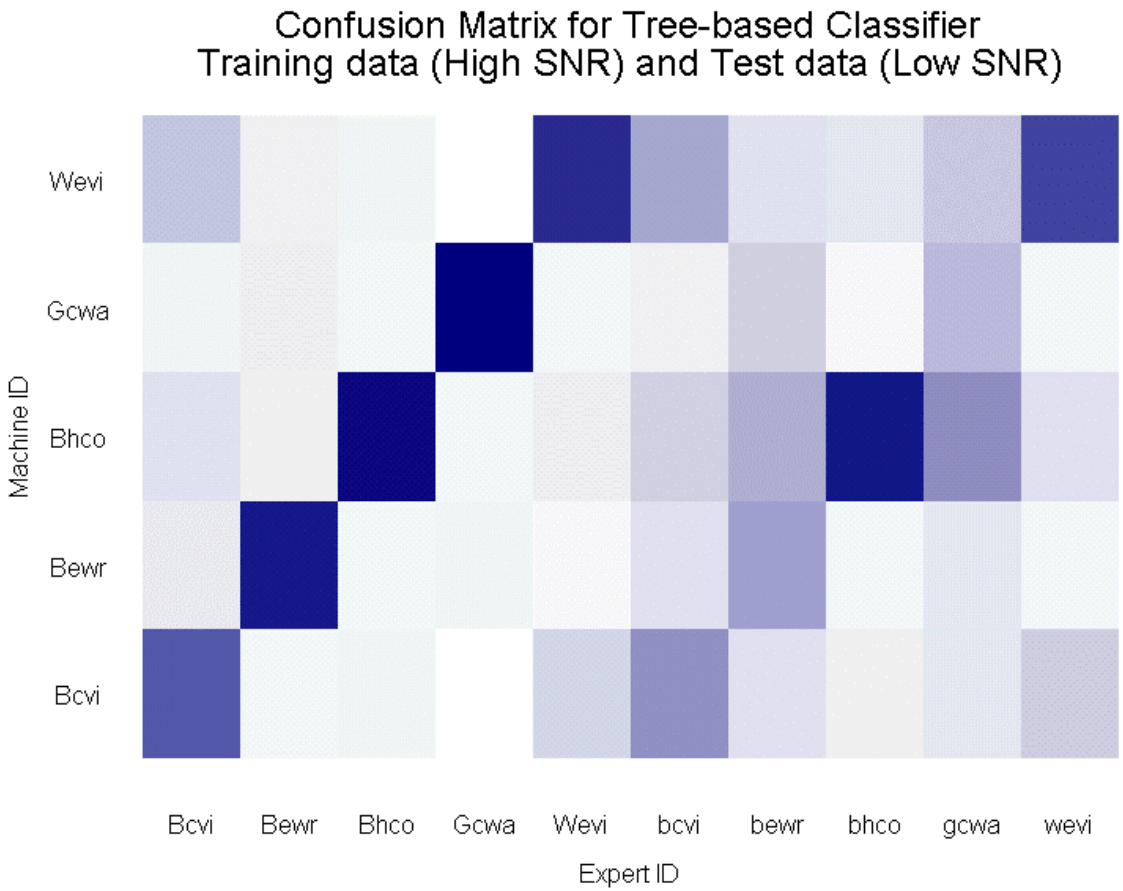
Operation of parametric shape-fitting signal detector

Signal Detection



Application of sinusoidal shape-fitting signal detector to a 30-second sequence of black-capped vireo songs.

Signal Classification



Concluding Remarks

- New passive acoustic monitoring technologies can relax or eliminate the need for site access by field biologists
- Extended spatial and temporal scale of these techniques enables monitoring of rare or otherwise cryptic species
- Can document species-specific stopover use on and around DoD installations
- Can improve the accuracy of population estimates by reducing sources of variance and bias that limit inferences from existing long-term data sets

Q & A

Thank you!